Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 20-21, 2022

Detection of Carbon Steel Loose Part on Secondary Side of Steam Generator Tube Through Historic Data Comparison of Bobbin Coil Eddy Current Signals

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1. Introduction

The integrity of steam generator tubes in pressurized water reactors are confirmed by the periodic in-service inspection using eddy current test methods. The dominant degradation mode of steam generators with alloy 600 tubing materials was corrosion. The new or replaced steam generators have been equipped with a more corrosion resistant tubing material of alloy 690, and degradation modes other than corrosion are becoming more prevalent. In addition to wears due to the contacts of tube to support structure and the tube to tube, wears by foreign objects on the secondary side of steam generators challenge tube integrity which can lead to primary to secondary leakage of coolant and unexpected outage of power plant. Therefore, earlier detection of foreign objects by eddy current technique is becoming more important [1]. In case where a small metallic foreign object is located in the tube support structure, it is almost impossible to detect the foreign object signals alone due to the large signal of metallic support structure masking the foreign object signals. In this work, the changes of eddy current signals from the presence of carbon steel loose part in the tube support structure are investigated in order to find out that the loose part can be detected through historical data comparison of eddy current signals [2].

2. Methods and Results

2.1 Manufacturing of Mock-up

A carbon steel loose part was machined from SA-106 Gr.B pipe, with dimension of width 10mm, length 10mm and thickness 2mm. The loose part was attached on the outer surfaces of alloy 690 steam generator tubes, and located into a mockup of eggcrate type tube support structure, made of type 409 stainless steel, as shown in Fig. 1.

In order to simulate the condition that the carbon steel loose part can be located randomly within the tube support structure, the center position of carbon steel loose part was adjusted relatively within the span of support structure, 1) at the center, 2) at the quarter, and 3) at the edge of the 50mm span length.

Fig. 1. Mock-up for carbon steel loose part in eggcrate type tube support structure.

2.2 Eddy Current Test

The mock-up tube was inspected with a ZETEC M-ULC bobbin coil probe and MIZ-70 eddy current data acquisition system. Multiple test frequencies of 300, 150, 100, 50 and 20 kHz were applied. Considering the large penetration depth of eddy current field at lower frequency, the 20 kHz signals from the both differential and absolute mode were analyzed principally.

2.3 Results and Discussion

Fig. 2 shows the results of comparison of 20kHz differential mode eddy current signals without carbon steel loose part (illustrated as brown lines) and with carbon steel loose part (illustrated as black lines) at the center of support structure span length. The location of loose part was depicted with a dark square symbol in the graph for reference. It was clearly notable that the support plate signals changed at the section where the carbon steel loose part was located. In the absolute mode eddy current signals shown in Fig.3, the changes of support plate signals were also identified.

Fig. 4 and Fig. 5 show the changes of differential and absolute mode eddy current signals for the carbon steel loose part located at the quarter of support structure span length, respectively. The signal changes were observed only at the section where the carbon steel loose part was located in both differential and absolute modes. Thus, it was expected that the carbon steel loose part in the support structure could be detected through historical data comparison of both differential and absolute mode eddy current signals.

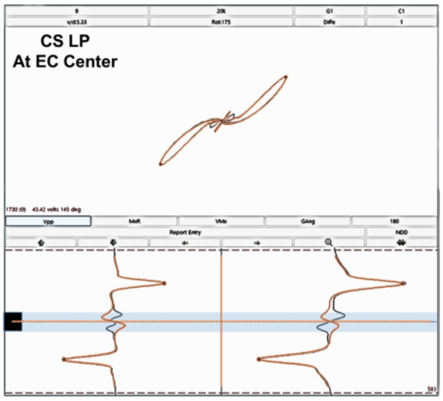

Fig. 2. Changes of 20kHz differential mode eddy current signal for the carbon steel loose part located at the center of support structure span length.

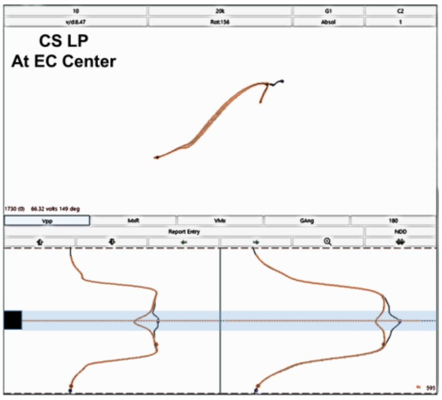

Fig. 3. Changes of 20kHz absolute mode eddy current signal for the carbon steel loose part located at the center of support structure span length.

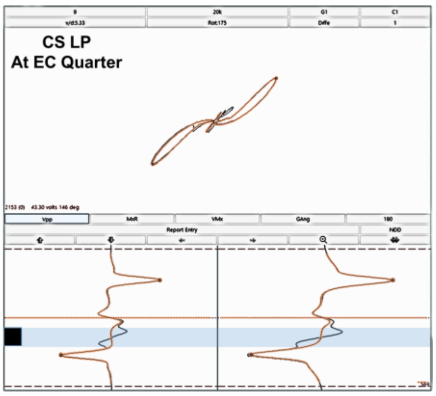

Fig. 4. Changes of 20kHz differential mode eddy current signal for the carbon steel loose part located at the quarter of support structure span length.

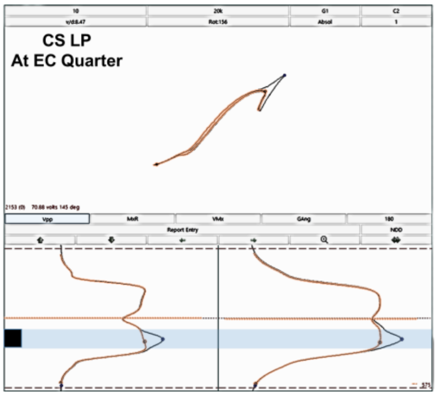

Fig. 5. Changes of 20kHz absolute mode eddy current signal for the carbon steel loose part located at the quarter of support structure span length.

Changes of differential and absolute mode eddy current signals for the carbon steel loose part located at the edge of support structure span length were shown in Fig. 6 and Fig. 7, respectively. The magnitude of signal changes was small and only the shape of signals was distorted slightly at the section where the carbon steel loose part was located.

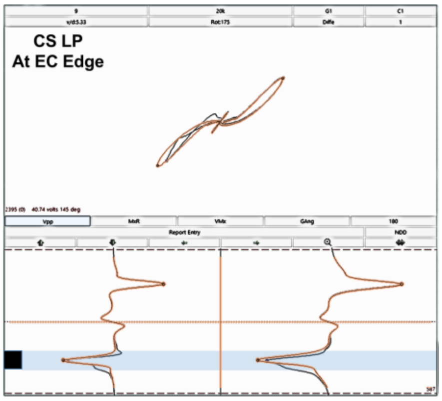

Fig. 6. Changes of 20kHz differential mode eddy current signal for the carbon steel loose part located at the edge of support structure span length.

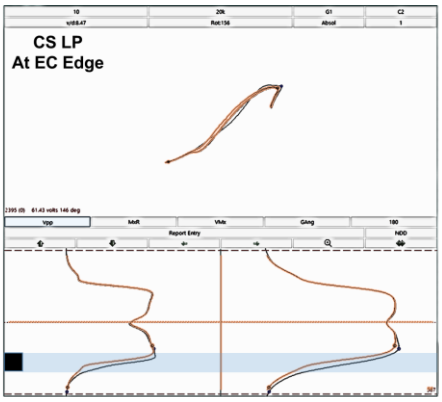

Fig. 7. Changes of 20kHz absolute mode eddy current signal for the carbon steel loose part located at the edge of support structure span length.

Thus, it can be anticipated that the carbon steel loose part located in the tube support structure can be detected through historical data comparison of bobbin coil eddy current low frequency signals in both differential and absolute mode, excluding the condition that the carbon steel loose part is located at the edge of the support structure.

3. Conclusions

Changes of eddy current signals from the carbon steel loose part randomly located in the tube support structure were investigated in order to find out that the loose part can be detected through historical data comparison of bobbin coil eddy current signals. The detection of carbon steel loose part was dependent upon its location within the support structure, and it was limitedly detectable excluding the condition that the carbon steel loose part is located at the edge of the support structure. In order to overcome this technical limit, the further work using a new eddy current inspection technique such as array coil probe is required.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2021M2E6A1096081).

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